

Darwinian Coevolution of Organizations and the Environment

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ABSTRACT

Darwinism offers a highly abstract and general meta-theoretical framework to help understand both natural and social evolution. This framework is of significance for ecological economics because it addresses the evolution and coevolution of biological systems and sets of human institutions. This paper outlines this framework and charts its historical origins since the time of Darwin. It is suggested that this over-arching framework is useful for ecological economics as a common meta-narrative within which more detailed examinations of both institutional and ecological mechanisms may be placed. Applying Darwinism in this manner does not mean that institutions or organizations are explained in purely biological terms: it means that Darwinian principles are not confined to biology.

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1. Introduction

Despite important adjustments and developments, neoclassical economics has maintained an approach to ecological matters wherein environmental policies are ultimately evaluated in terms of the utility of individuals.¹ In practice, monetary evaluations or subjective rankings are used as surrogates for individual utility. An obvious problem with this utilitarian approach is that environmental policies are evaluated ultimately in terms of individual satisfaction, and some individual evaluations and pleasures may be inconsistent with ecological sustainability.

Furthermore, if we take current consumer preferences as sovereign, then policy makers will ignore the vital task of educating people that their behaviour is ecologically unsustainable, and persuading them to adjust their values and priorities. The criterion of consumer sovereignty based on existing preferences overlooks the dependence of individual goals on their cultural and institutional context. Environmental problems impinge over years or decades, and it is unreasonable to assume that current preferences will remain constant (Norton *et al.* 1998). Utilitarian preference functions also ignore matters of morality and commitment that are vital to deal with environmental problems (Hodgson 1997; Sagoff 1998).

The International Society for Ecological Economics and the journal *Ecological Economics* were founded in response to these perceived limitations of neoclassical environmental economics. Economists and ecologists were brought together to develop theories and policies that are superior to those derived from narrow utilitarian and cost-benefit approaches (Gowdy and Erickson 2005).

However, problems concerning common metrics of evaluation remain. A sensible and pragmatic response has been to insist on pluralist approaches and combinations of monetary and ecological evaluations to guide policy (Norgaard 1989, 1994; Vatn 2005). But ultimately different measures must be reconciled to make a decision.

Darwinian theory does not provide a solution to this problem. Nevertheless it makes an important step in the right direction by establishing a common framework within which the coevolution of the environment and human institutions may be considered. At least at an abstract level, evaluations of the sustainability of ecosystems can be integrated with

¹ This paper uses material from Hodgson (2004) and Aldrich et al. (2008). The author is very grateful to Giorgos Kallis for comments on an earlier version of this essay.

considerations of the robustness of human organizations, particularly to environmental shocks.²

Within ecological economics the concept of coevolution has been the subject of an unresolved debate (Norgaard 1994, 2005; Winder 2005; Winder et al. 2005; Kallis 2007). In this context the term ‘coevolution’ has been used to refer to processes where there is an interaction between human culture or institutions, on the one hand, and the biophysical context, on the other.³ Nick Winder (2005) and his colleagues (Winder et al. 2005) have objected that such a definition is far too loose and covers a huge variety of types of possible interactions.

In response, ‘coevolution’ has a broad set of meanings because the word ‘evolution’ has also in practice been subject to a wide variety of interpretations and connotations, including highly questionable notions of predestination, inevitable progress, preformation or whatever. With this historical baggage there is little point trying to narrow down either term. It is best to use the term evolution broadly to refer to significant change.

I argue here for the more specific term ‘Darwinian coevolution’. As elaborated below, Darwinism applies to the ontological case of ‘complex population systems’ where there are multiple entities struggling for survival with scarce resources.⁴ Both the social and the natural world contain ‘complex population systems’. A key point is that the Darwinian principles of variation, inheritance and selection are *necessary* (but not sufficient) to explain the ongoing evolution of such systems, including socio-economic systems.⁵

Consequently, Darwinian coevolution applies to cases of significant interaction – involving in the human social world or the natural world (or both) – *populations* of entities. Such interactions necessarily involve the Darwinian principles of variation, inheritance and selection, in at least one of the two domains. Accordingly, the application of pesticides by humans to their natural environment leads to the Darwinian selection of pests. There are many suggestions on the way in which the natural world may impact on human culture and institutions and their development, including climatic and other factors (Diamond 1997; Acemoglu et al. 2002).

The following section of this paper focuses on the historical development of the idea that abstract Darwinian principles apply to socio-economic evolution as well the evolution in the

² I define institutions as systems of established and prevalent social rules that structure social interactions. Contrary to a prominent misinterpretation, Douglass North himself makes it clear that he also regards organizations as institutions (Hodgson 2006). I define an organization as a special type of institution involving (a) criteria to establish its boundaries and to distinguish its members from its non-members, (b) principles of sovereignty concerning who is in charge and (c) a structure of command and responsibility delineating roles within the organisation. All organizations are institutions, but not all institutions are organizations (language being an example).

³ In a different context ‘coevolution’ refers to the interaction of human culture and human genes (Boyd and Richerson 1985, Durham 1991). Instead I refer to social-ecological coevolution here.

⁴ Scarcity is a central concept in mainstream economics but (with rare exceptions such as Daly 1974) it is rarely dissected in detail. It is used here to resources that are not *immediately* available for an entity: their capture requires effort and costs. It does not necessarily imply that a resource is *globally* scarce, although that of course is the reality concerning many physical resources. See section 3 below.

⁵ There is an ongoing debate in economics concerning this argument. See Aldrich et al. (2008) for a recent instalment of this controversy, with references to opposing views.

biological world. Section three outlines the ontological and theoretical principles involved. Section four concludes by suggesting how these ideas may have further relevance for the development of ecological economics.

2. Historical background

It is widely accepted that natural organisms evolve according to Darwinian principles. It is not so widely appreciated that the same principles can be applied to the evolution of social phenomena, including institutions and organizations. Charles Darwin (1859, pp. 422-3; 1871, vol. 1, p. 162 n.) himself considered the possibility that natural selection operates upon the elements of language. Darwin (1871, vol. 1, p. 162 n.) also sympathetically addresses attempts by Walter Bagehot to apply Darwinian principles to political evolution.⁶ Darwin (1871, vol. 1, pp. 162-6) also proposed that tribal groups with moral and other propensities that served their common interests would be favored by natural selection.

Several scholars followed these hints that the principles of selection, variation and inheritance may have a wider applicability than to biological organisms alone, including to the evolution of human society. William James (1880, 441) opened a prescient essay with the observation of a ‘remarkable parallel ... between the facts of social evolution on the one hand, and of zoölogical evolution as expounded by Mr. Darwin on the other.’ However, his discussion was largely confined to the selection of ideas. Samuel Alexander (1892) and Benjamin Kidd (1894) also wrote on the natural selection of ethical principles.

But while several thinkers believed that Darwinian principles apply in this sphere, they were applied loosely and incompletely. These earlier writers failed to examine the units of selection and processes of replication in more detail, including the possible ‘natural selection’ of social structures or institutions. When they considered Darwinian selection, it was loosely to individuals or collections of individuals.

Accordingly, these early extensions of Darwinian principles to social evolution failed to establish the social units of replication and selections, other than to refer imprecisely to societies or groups. It was not explained why human social evolution involved anything more than the selection of individuals. After all, the selection or fitness advantage of one group over another may simply result from the selection or fitness advantages of the members of the more adapted group. In this case, group selection or fitness amount to nothing more than individual selection or fitness.

In the 1890s, and independently of each other, two writers first clearly formulated the notion that there were social units of selection, irreducible to individuals, to which Darwinian principles might apply. The first of these was the Scottish philosopher David George Ritchie, who argued that Darwinian principles of variation, heredity and selection applied to the evolution of social institutions as well as to organisms (Ritchie 1891). Despite detailed differences of evolutionary mechanism, the ‘range’ of Darwinian theory could be extended from the biological to the social sphere. In a prescient passage, Ritchie (1896, 170-1) wrote:

But in asserting that human society presents many phenomena that cannot be accounted for by natural selection in its purely biological sense, I am not denying the truth of the

⁶ Bagehot’s essays appeared in the *Fortnightly Review* from 1867 to 1869 and were later republished in book form (Bagehot, 1872).

theory, but rather extending its range. There is going on a 'natural selection' of ideas, customs, institutions, irrespective of the natural selection of individuals and of races.

This quotation contains a path-breaking recognition that Darwinian principles could be applied to social evolution and to non-biological units of replication or selection. The idea of 'extending the range' of Darwinian principles to outside the biological sphere tallies with what was 87 years later described by Dawkins (1983) as 'Universal Darwinism'. The work of Ritchie and others shows that the idea of generalizing Darwinian principles was established in the nineteenth rather than the twentieth century. A key innovation by Ritchie was to recognize that the units of replication or selection could be social entities such as customs and institutions, rather than individuals alone.

The second scholar to write of institutions as units of selection was Thorstein Veblen (1897, p. 390) who wrote that the 'economic exigencies' of the industrial process 'afford the definitive test of fitness in the adaptation of all human institutions by a process of selective elimination of the economically unfit.' Veblen (1899, p. 188) also declared:

The life of man in society, just like the life of other species, is a struggle for existence, and therefore it is a process of selective adaptation. The evolution of social structure has been a process of natural selection of institutions. The progress which has been and is being made in human institutions and in human character may be set down, broadly, to a natural selection of the fittest habits of thought and to a process of enforced adaptation of individuals to an environment which has progressively changed with the growth of community and with the changing institutions under which men have lived.

Veblen (1899, p. 207) wrote also in the same work of 'the law of natural selection, as applied to human institutions'. The decisive implication was that Darwinism could be applied to human society without necessarily reducing explanations of social phenomena entirely to individual psychology or biology. As Veblen (1909, p. 300) wrote:

If ... men universally acted not on the conventional grounds and values afforded by the fabric of institutions, but solely and directly on the grounds and values afforded by the unconventionalised propensities and aptitudes of hereditary human nature, then there would be no institutions and no culture.

Veblen made it clear that the application of general Darwinian principles to socio-economic phenomena does not mean that the latter are explained in purely biological terms. Darwinism is too important to be left to the biologists.

In the twentieth century, similar applications of generalized Darwinian principles to the evolution of social entities were proposed by Albert Galloway Keller (1915) and others, but the idea fell out of favour until after the Second World War, being revived by the archaeologist V. Gordon Childe (1951) and the psychologist Donald T. Campbell (1965). Dawkins's (1983) later presentation lacks some of the sophistication of earlier accounts, relying principally on his vaguely-defined cultural unit of the 'meme'. By the turn of the new millennium, the idea of generalizing Darwinian principles to social entities began to take hold among evolutionary economists (Nightingale, 2000; Hodgson, 2002; Hodgson and Knudsen, 2006a; Aldrich *et al.* forthcoming 2008).

3. Ontology and basic principles

A key step in the generalization of core Darwinian principles is the general specification of the broad type of system to which these ideas apply. The claim is that Darwinian principles apply to what may be described as ‘complex population systems’. Such systems may be biological or social. They involve populations of entities. Populations are defined by members of a type that are similar in key respects, but within each type there is some degree of variation, due to genesis or circumstances.

Entities within these populations have limited capacities to consume materials and energy from their environment and they have mechanisms to process information useful for survival. These entities may or may not have a developed brain or memory. They may or may not be capable of reflecting on their circumstances and remembering past or imagining future behaviours.

All these entities are mortal and degradable, and they need to consume materials and energy in order to survive or minimize degradation. However, because they do not have access to all environmental resources at once, these entities face an omnipresent problem of *local and immediate scarcity*, as well as problems of pressing and global resource constraints. These circumstances present specific problems that the entities must solve to minimize degradation and raise their chances of survival. In short, these entities are engaged in a *struggle for existence* (Darwin 1859, pp. 62-63).

We assume some capacity to retain and pass on to others workable solutions to problems they have faced. The advantages of retaining such problem solutions or adaptations are obvious in avoiding the risks and costs of learning them anew. Entities possess some capacity to pass on to others information about such workable solutions, providing the foundation for a trans-generational cumulative growth of problem-solving ‘knowledge.’ This is the basis of the Darwinian *principle of inheritance*, which refers to a broad class of mechanisms, including those of ‘replication’ and ‘descent’ (Mayr 1991), by which information concerning adaptations is retained, preserved, passed on or copied through time.

In sum, a complex population system involves populations of non-identical (intentional or non-intentional) entities that face locally scarce resources and problems of survival. The entities retain some adaptive solutions to such problems and may pass them on to other entities. Examples of populations in such systems are plentiful both in nature and in human society. They include every biological species, from amoeba to humans. They would include self-replicating automata, of the type discussed by John von Neumann (1966). In addition, and importantly for the social scientist, they include human organisations, as long as we regard organisations as cohesive entities having some capacity for the retention and replication of problem solutions.

In this manner, at a high level of abstraction, the common ontological features of all complex population systems are established, including in nature and human society, without ignoring the huge differences of detail between or within these domains.

On reflection it becomes clear that the evolution of such a system *must* involve the three Darwinian principles of variation, inheritance and selection. These abstract principles do not themselves provide all the necessary details, but nevertheless they must be honoured, for otherwise the explanation of evolution will be inadequate.

First, there must be some explanation of how variety is generated and replenished in a population. Second, there must be an explanation for how useful information concerning

solutions to particular adaptive problems is retained and passed on. This requirement follows directly from the above assumptions concerning the broad nature of complex population systems, wherein there must be some mechanism by which adaptive solutions are copied and passed on. This is the *principle of inheritance*. Third, and not least, there must be an explanation of the fact that entities differ in their longevity and fecundity. In given contexts, some entities are more adapted than others, some survive longer than others, and some are more successful in producing offspring or copies of themselves. This is the *principle of selection*.

Selection involves an anterior set of entities, each interacting with its environment and somehow being transformed into a posterior set where all members of the posterior set are sufficiently similar to some members of the anterior set, and where the resulting frequencies of posterior entities depend upon their properties in the environmental context (Price 1970, 1995; Hodgson and Knudsen 2006b). Through selection a population gradually adapts in response to environmental factors. But selection does not necessarily lead to optimal or near-optimal outcomes.

A further important point follows from the ontological specification of complex population systems. We consider multiple entities, each carrying information relevant for their development and survival. Some of this information can be passed on to other entities. Within the philosophy of biology, the term ‘interactor’ has been devised to describe the entities, and ‘replicator’ to describe their components that deal with the retention, use and replication of relevant information.

David Hull (1988, p. 408) defined an interactor as ‘an entity that directly interacts as a cohesive whole with its environment in such a way that this interaction *causes* replication to be differential’. A number of authors have developed and refined the definition of a replicator. An emerging consensus is that replication involves a causal relationship between two or more entities, where there is substantial similarity between the original and replicated entities, and where information concerning adaptive solutions to survival problems is passed from one set of entities to another (Sterelny et al. 1996; Godfrey-Smith 2000; Sperber 2000). The definitional characteristics of causality, similarity and information transfer are common to these accounts, notwithstanding a case for further refinement (Hodgson and Knudsen 2008).

Clearly, there are cohesive evolving entities, in both the biological and social domains, such as organisms and organizations. The question arises as to whether such entities in the social world interact with their environments in ways that cause the differential replication of relevant stored information. If we consider economic competition between firms, then the elimination of some and the prosperity of others leads to the differential copying (by collaboration or imitation) of routines, techniques, management procedures, and so on (Nelson and Winter, 1982). If any of these elements qualify as social replicators, then clearly they are very different from biological replicators such as genes. There are crucial differences concerning how the information is stored, how it is replicated, and how faithful is the replication. The general definition of a replicator has to be deployed with care. Nevertheless, there is at least a *prime facie* case for identifying interactors and replicators in the social domain.⁷

⁷ Hodgson and Knudsen (2004) propose that many firms have the characteristics of interactors. But this is not true for institutions (such as language) that are not organizations. Hence the choice of the narrower term in the title of this essay.

These conceptual developments help us escape from the vagaries of the ‘memetics’ where there is no consensus on what the meme is, and whether it is a replicator or interactor. The careful definitions by philosophers of key Darwinian concepts point to possible social interactors such as organizations, and possible social replicators such as habits and routines.

Some critics claim that a sharp replicator-interactor distinction is unviable or inappropriate in social evolution. They share this stance with others. Those evolutionary economists who resist a generalized Darwinism, exclusively gene-centred theorists, and biological reductionists, all deny the existence of social replicators and interactors.

4. Some implications for ecological economics

Although generalized Darwinian principles apply to both social and biological systems, they offer no short-cut theoretical explanations or answers. As in biology, detailed examination of the particular mechanisms is also required. Darwinian principles are not like Newtonian laws that can predict accurately the motion of bodies through space. Instead, Darwinism is a general meta-theoretical framework within which particular auxiliary explanations must be placed. The nature of these auxiliary explanations will vary from domain to domain.

Nevertheless, the provision of this meta-theoretical framework is an important step. In particular, the idea of generalizing Darwinism to socio-economic evolution challenges the longstanding idea among social scientists that social and biological phenomena should be completely partitioned – that social scientists have little to learn from biology and vice versa. A generalized Darwinism is consistent with the idea that human society is embedded in the natural world and depends upon it for its survival.

A generalized Darwinism systematizes the process of empirical inquiry and organizes detailed knowledge pertaining to a wide variety of evolutionary processes. Furthermore, Darwinian ideas have important implications for social scientists concerning the rationality and psyche of human agents (Richards 1987). Assumptions concerning human agents must be consistent with our understanding of human evolution. Darwinian evolution involves the development, retention and selection of information concerning adaptive solutions to survival problems faced by organisms in their environment. Darwinism constantly raises questions of causality and requires explanations of origin. This applies in particular to the dispositional programs behind human thought and behaviour. Contrary to much mainstream economics, individuals and their preferences cannot simply be taken as given.

Crucially, Darwinism focuses our attention on the possible mechanisms through which variety is preserved and created. It is remarkable that two of the most important mechanisms identified by Darwin (1859) and retained in modern biology involve locational considerations. First, the migration of a group to another area with a different physical environment, and second the use or creation of different niches, remain two of the most important mechanisms to explain speciation. Related ideas would seem to transfer directly to the social or economic domain. In these cases the new environment, and the (relative) isolation of a group from the majority, create new opportunities for variation.

Similar arguments apply to human institutions as well as biological organisms, notwithstanding the fact that the nature and mechanisms of mutation and separation are very different. The general ideas of mutation and physical separation particularly apply to the evolution of languages and all sorts of customs. For example, relative isolation and language change leads to subdivision and often the creation of new languages. Furthermore, there is

now a growing literature on how firms may perform differently in different contexts, such as under different regulatory regimes or among different types of financial institutions (Amable, 2000; Aoki, 2001; Hall and Soskice, 2001; Boyer, 2005; Kenworthy, 2006).

Not only are the above considerations of general importance for understanding the evolution of organizations, they are of particular relevance for ecological economics. Much of the policy agenda for ecological economics is a matter of appropriate institutional design, to establish incentives that are consistent with environmental goals, to process flows of information to guide policy, and to deal with unforeseen disturbances and shocks.

In this vein there is the important literature on the robustness of socio-ecological systems, which helps to identify social and ecological vulnerabilities to disturbances. John Anderies et al. (2004) for example identify the link between resource users and public infrastructure providers as a key variable affecting such robustness. They develop a set of appropriate institutional design principles.

In line with the Darwinian emphasis on the role of variety in the processes of adaptation and selection, C. Dustin Becker and Elinor Ostrom (1995) emphasise the importance of institutional diversity in coping with complex developments in environmental systems. Similar themes are prominent in a special issue of the *Journal of Institutional Economics* on institutions and ecosystems (Janssen 2006).

Much of this middle-range literature fails to mention Darwinism. But for similar reasons many applied biologists are not obliged to refer to general Darwinian evolutionary principles when they carry out concrete studies. Much of biology proceeds by assuming but not mentioning the core Darwinian principles of variation, inheritance and selection. Darwinian theory is at a high level of abstraction. Middle-range theory has to be consistent with this theory but it does not necessarily involve applying it at every turn. Instead, Darwinian theory is a way of organising our understanding of different evolving systems and organising explanations that operate on different levels.

Moreover, a more explicit recognition of the role of Darwinism in these contexts may stimulate some useful theoretical developments on interactions between organizations and ecosystems. Darwinism may provide a meta-theoretical framework wherein fragmented and diverse insights may be integrated and further developed. Furthermore, although Darwinism does not immediately provide the answers, this unifying framework may help to generate some basic principles and policy guidelines that span the social and ecological domains. It may facilitate the development of our understanding of the institutional developments that are vital to deal with pressing environmental problems, including climate change.

References

- Acemoglu, Daron, Johnson, Simon and Robinson, James A. (2002) 'Reversal of Fortune: Geography and Institutions in the Making of the Modern Income Distribution', *Quarterly Journal of Economics*, **117**(4), November, pp. 1231-94.
- Alexander, Samuel (1892) 'Natural Selection in Morals', *International Journal of Ethics*, **2**(4), July, pp. 409-39.

- Aldrich, Howard E., Geoffrey M. Hodgson, David L. Hull, Thorbjørn Knudsen, Joel Mokyr and Viktor J. Vanberg (2008) 'In Defence of Generalized Darwinism', *Journal of Evolutionary Economics* (forthcoming 2008).
- Amable, Bruno (2000) 'Institutional Complementarity and Diversity of Social Systems of Innovation and Production', *Review of International Political Economy*, 7(4), Winter, pp. 645-87.
- Anderies, John M., Marco A. Janssen, and Elinor Ostrom (2004) 'A Framework to Analyze the Robustness of Social-Ecological Systems from an Institutional Perspective', *Ecology and Society*, 9(1), 18 [online] URL: <http://www.ecologyandsociety.org/vol9/iss1/art18/>
- Aoki, Masahiko (2001) *Toward a Comparative Institutional Analysis* (Cambridge, MA: MIT Press).
- Bagehot, Walter (1872) *Physics and Politics, or, Thoughts on the Application of the Principles of 'Natural Selection' and 'Inheritance' to Political Society* (London: Henry King).
- Becker, C. Dustin and Elinor Ostrom (1995) 'Human Ecology and Resource Sustainability: The Importance of Institutional Diversity', *Annual Review of Ecology and Systematics*, 26, November, pp. 113-133.
- Boyd, Robert and Richerson, Peter J. (1985) *Culture and the Evolutionary Process* (Chicago: University of Chicago Press).
- Boyer, Robert (2005) 'Coherence, Diversity, and the Evolution of Capitalisms – The Institutional Complementarity Hypothesis', *Evolutionary and Institutional Economics Review*, 2(1), October, pp. 43-80.
- Campbell, Donald T. (1965) 'Variation, Selection and Retention in Sociocultural Evolution', in Barringer, H. R., Blanksten, G. I. and Mack, R. W. (eds) (1965) *Social Change in Developing Areas: A Reinterpretation of Evolutionary Theory* (Cambridge, MA: Schenkman), pp. 19-49.
- Childe, V. Gordon (1951) *Social Evolution* (London: Watts).
- Daly, Herman E. (1974) 'The Economics of the Steady State', *American Economic Review (Papers and Proceedings)*, 64(2), May, 15-21.
- Darwin, Charles R. (1859) *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, 1st edn. (London: Murray).
- Darwin, Charles R. (1871) *The Descent of Man, and Selection in Relation to Sex*, 1st edn., 2 vols (London: Murray and New York: Hill).
- Dawkins, Richard (1983) 'Universal Darwinism', in D. S. Bendall (ed.) (1983) *Evolution from Molecules to Man* (Cambridge: Cambridge University Press), pp. 403-25.
- Diamond, Jared (1997) *Guns, Germs and Steel: The Fates of Human Societies* (New York: W. W. Norton).
- Durham, William H. (1991) *Coevolution: Genes, Culture, and Human Diversity* (Stanford: Stanford University Press).
- Godfrey-Smith, Peter (2000) 'The Replicator in Retrospect', *Biology and Philosophy*, 15, pp. 403-23.

- Gowdy, John and Erickson, Jon D. (2005) 'The Approach of Ecological Economics', *Cambridge Journal of Economics*, **29**(2), March, pp. 207-22.
- Hall, Peter A. and Soskice, David (2001) *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage* (Oxford: Oxford University Press).
- Hodgson, Geoffrey M. (1997) 'Economics, Environmental Policy and the Transcendence of Utilitarianism' in Foster, John (ed.) (1997) *Valuing Nature? Ethics, Economics and the Environment* (London and New York: Routledge), pp. 48-63.
- Hodgson, Geoffrey M. (2002) 'Darwinism in Economics: From Analogy to Ontology', *Journal of Evolutionary Economics*, **12**(2), June, pp. 259-81.
- Hodgson, Geoffrey M. (2004) *The Evolution of Institutional Economics: Agency, Structure and Darwinism in American Institutionalism* (London and New York: Routledge).
- Hodgson, Geoffrey M. (2006) 'What Are Institutions?' *Journal of Economic Issues*, **40**(1), March, pp. 1-25.
- Hodgson, Geoffrey M. and Knudsen, Thorbjørn (2004) 'The Firm as an Interactor: Firms as Vehicles for Habits and Routines', *Journal of Evolutionary Economics*, **14**(3), July, pp. 281-307.
- Hodgson, Geoffrey M. and Knudsen, Thorbjørn (2006a) 'Why We Need a Generalized Darwinism: and Why a Generalized Darwinism is Not Enough', *Journal of Economic Behavior and Organization*, **61**(1), September, pp. 1-19.
- Hodgson, Geoffrey M. and Knudsen, Thorbjørn (2006b) 'The Nature and Units of Social Selection', *Journal of Evolutionary Economics*, **16**(5), December 2006, pp. 477-89.
- Hodgson, Geoffrey M. and Knudsen, Thorbjørn (2008) 'Information, Complexity and Generative Replication', *Biology and Philosophy*, **43**(1), pp. 47-65.
- Hull, David L. (1988) *Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science* (Chicago: University of Chicago Press).
- James, William (1880) 'Great Men, Great Thoughts, and the Environment', *Atlantic Monthly*, **46**, pp. 441-59.
- Janssen, Marco A. (2006) 'Historical Institutional Analysis of Social-Ecological Systems', *Journal of Institutional Economics*, **2**(2), August, pp. 127-31.
- Kallis, Giorgos (2007) 'When is it Coevolution?' *Ecological Economics*, **62**(1), pp. 1-6.
- Keller, Albert Galloway (1915) *Societal Evolution: A Study of the Evolutionary Basis of the Science of Society* (New York: Macmillan).
- Kenworthy, Lane (2006) 'Institutional Coherence and Macroeconomic Performance', *Socio-Economic Review*, **4**(1), January, pp. 69-91.
- Kidd, Benjamin (1894) *Social Evolution* (London and New York: Macmillan).
- Mayr, Ernst (1991) *One Long Argument: Charles Darwin and the Genesis of Modern Evolutionary Thought* (Cambridge, MA: Harvard University Press).
- Nelson, Richard R. and Winter, Sidney G. (1982) *An Evolutionary Theory of Economic Change* (Cambridge, MA: Harvard University Press).
- Neumann, John von (1966) *Theory of Self-Reproducing Automata*, ed. and completed by Arthur W. Burks (Urbana: University of Illinois Press).

- Nightingale, John (2000) 'Universal Darwinism and Social Research: The Case of Economics', in Barnett, William A., Chiarella, Carl, Keen, Steve, Marks, Robert and Schnabl, Hermann (eds) (2000) *Commerce, Complexity, and Evolution* (Cambridge and New York: Cambridge University Press), pp. 21-36.
- Norgaard, Richard B. (1989) 'The Case for Methodological Pluralism', *Ecological Economics*, 1(1), February, pp. 37-57.
- Norgaard, Richard B. (1994) *Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future* (London and New York: Routledge).
- Norgaard, Richard B. (2005) 'Bubbles in a Back Eddy: A Commentary on "The Origin, Diagnostic Attributes and Practical Application of Coevolutionary Theory"', *Ecological Economics*, 54(4), pp. 362-5.
- Norton, Bryan, Robert Costanza and Richard C. Bishop (1998) 'The evolution of preferences: Why "sovereign" preferences may not lead to sustainable policies and what to do about it', *Ecological Economics*, 24(2-3), February, pp. 193-211.
- Price, George R. (1970) 'Selection and Covariance', *Nature*, 227, pp. 520-1.
- Price, George R. (1995) 'The Nature of Selection', *Journal of Theoretical Biology*, 175, pp. 389-96.
- Richards, Robert J. (1987) *Darwin and the Emergence of Evolutionary Theories of Mind and Behavior* (Chicago: University of Chicago Press).
- Ritchie, David G. (1891) *Darwinism and Politics*, 2nd edn. (London: Swan Sonnenschein).
- Ritchie, David G. (1896) 'Social Evolution', *International Journal of Ethics*, 6(2), pp. 165-81.
- Sagoff, Mark (1998) 'Aggregation and deliberation in valuing environmental public goods: A look beyond contingent pricing', *Ecological Economics*, 24(2-3), February, pp. 213-230
- Sperber, Dan (2000) 'An Objection to the Memetic Approach to Culture', in Aunger, Robert (ed.) (2000) *Darwinizing Culture: The Status of Memetics as a Science* (Oxford and New York: Oxford University Press), pp. 162-73.
- Sterelny, Kim, Smith, Kelly C. and Dickison, Michael (1996) 'The Extended Replicator', *Biology and Philosophy*, 11, pp. 377-403.
- Vatn, Arild (2005) *Institutions and the Environment* (Cheltenham and Northampton: UK and MA, USA)
- Veblen, Thorstein B. (1897) Review of *Essais sur la conception matérialiste de l'histoire* by Antonio Labriola, in *Journal of Political Economy*, 5(3), June, pp. 390-1.
- Veblen, Thorstein B. (1899) *The Theory of the Leisure Class: An Economic Study in the Evolution of Institutions* (New York: Macmillan).
- Veblen, Thorstein B. (1909) 'Fisher's Rate of Interest', *Political Science Quarterly*, 24(2), June, pp. 296-303.
- Winder, Nick (2005) 'Modernism, Evolution and Vaporous Vision of Future Unity: Clarification in Response to Norgaard', *Ecological Economics*, 54(4), pp. 366-9.
- Winder, Nick, McIntosh, Brian S. and Jeffrey, Paul (2005) 'The Origin, Diagnostic Attributes and Practical Application of Co-evolutionary Theory', *Ecological Economics*, 54(4), pp. 347-61.